U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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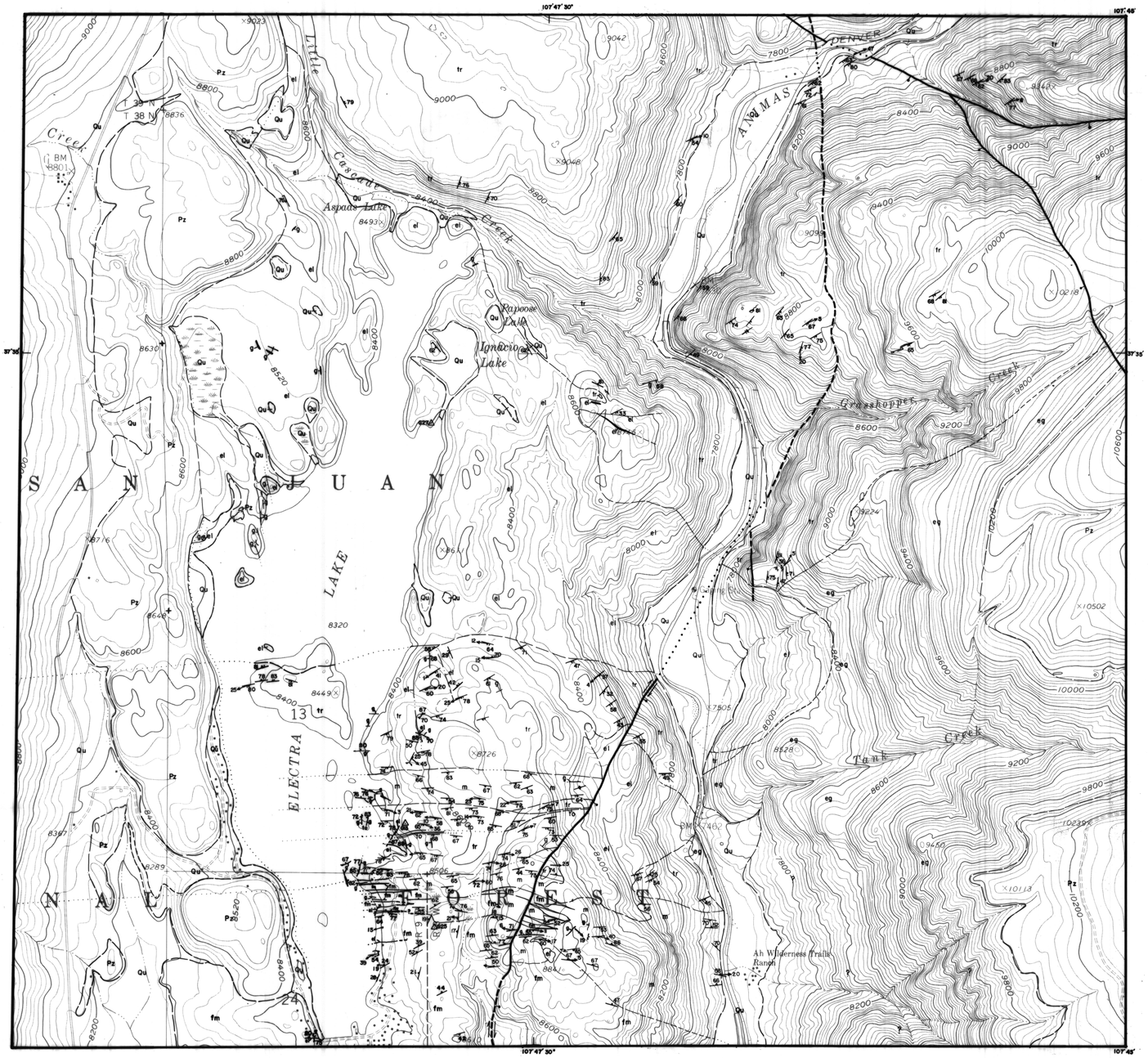
PLATE 1 OF 2



Base from U.S. Geological Survey 7.5 minute topographic series, 1:24,000: Electra Lake, 1960

Geologic mapping by D.A. Gonzales with assistance from Greg S. Siek during the summer of 1993.

MN
13°
231 MILS
APPROXIMATE MEAN DECLINATION, 1982

SCALE 1:15,000
0 1 MILE
0 1 KILOMETER

CONTOUR INTERVAL 40 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

COLORADO
LOCATION OF MAP

GEOLOGIC MAP OF THE ELECTRA LAKE AREA, WESTERN NEEDLE MOUNTAINS, COLORADO

By

David A. Gonzales

1994

CORRELATION OF MAP UNITS

Qu — QUATERNARY

Unconformity

Pz — CAMBRIAN TO MISSISSIPPIAN

Unconformity

Intrusive Rocks

ca. 1440-1430 Ma — el, eg, g — MIDDLE PROTEROZOIC

Rocks are Multiply Deformed & Metamorphosed to Amphibolite Facies

Intrusive Rocks (All Pre- or Syndeformational)

Metamorphosed Gabbroic Sills & Dikes (Not Shown On Map)

ca. 1770-1755 Ma — tr, to

Volcanogenic & Associated Intrusive Rocks

ca. 1805-1795 Ma — m, fm

EARLY PROTEROZOIC

DESCRIPTION OF MAP UNITS

Qu **Surficial Deposits Undifferentiated (Quaternary)**--Unconsolidated deposits of sand and gravel confined to major drainage basins and their tributaries. Also includes soil, bogs, and ponds through which little or no bedrock is exposed and which are commonly covered with a thick blanket of vegetation.

Pz **Paleozoic Rocks Undifferentiated (Upper Cambrian-Lower Mississippian)**--Includes the Upper Cambrian Ignacio Quartzite, Devonian Elbert Formation and Ouray Limestone, and Lower Mississippian Leadville Limestone.

g **Granitoid Dikes and Sills (Middle Proterozoic)**--Aplite, pegmatite, and fine- to coarse-grained granitic dikes and sills that cut the Electra Lake Gabbro, Twilight Gneiss, and Irving Formation. These intrusive bodies range from centimeters to tens of meters in thickness and can extend hundreds of meters along strike. Locally they have a weak to strong E-W foliation.

el **Electra Lake Gabbro (Middle Proterozoic)**--Fine- to very coarse-grained subophitic to ophitic gabbro, diorite, and granodiorite; locally contains irregular zones of associated pegmatite that crop out over areas of several to tens of square meters. These rocks are generally massive but locally exhibit a weak to strong northwest-southeast trending primary flow foliation defined by subparallel aligned blades of pyroxene and laths of plagioclase. Essential constituents listed in a general paragenetic sequence are: clinopyroxene and orthopyroxene, andesine to labradorite, hornblende, biotite, and quartz; pegmatitic phases also contain perthitic microcline. Accessory minerals include apatite, deuteric epidote, magnetite, and zircon; secondary alteration of plagioclase to sericite and mafic minerals to chlorite is common in these rocks. A sample of pegmatitic gabbro collected at station G27 yields a U-Pb zircon age of 1435 ± 2 Ma.

eg **Eolus Granite (Middle Proterozoic)**--Granite to quartz monzonite that generally contain phenocrysts of perthitic microcline, 1-5 cm in length, that are set in a medium- to very coarse-grained groundmass dominated by biotite, hornblende, plagioclase, potassium feldspar, and magnetite. Near its contact with the Twilight Gneiss on the west side of the Animas River canyon, the Eolus Granite locally contains a, weak to strong, wavy foliation that trends roughly east-west. A sample of porphyritic granite collected from the Eolus Granite approximately 16 kilometers east of the study area gives a U-Pb zircon age of 1435 ± 7 Ma.

Twilight Gneiss (Early Proterozoic Intrusive Complex)

to **Tonalitic Gneiss**--Medium- to coarse-grained, strongly foliated gneiss interpreted as metamorphosed tonalitic to dioritic plutonic rocks. These rocks are characterized by a ribbony foliation defined by alternating quartzo-feldspathic and mafic ribbons, and pronounced mineral lineations. Principal constituents are quartz, plagioclase, biotite, hornblende, epidote, and garnet with accessory opaque minerals, apatite, zircon, and sphene. Most samples show partial replacement of mafic minerals and garnet by chlorite, and plagioclase by sericite. The color index of these rocks is between 30-80%. A sample of this lithology collected at station G13 yields a U-Pb zircon age of 1759 ± 6 Ma.

tr **Trondhjemitic Gneiss**--Fine- to coarse-grained gneiss that typically contains subequant to lenticular plagioclase crystals and ellipsoidal polygranular aggregates of quartz that are set in a finer grained groundmass composed largely of quartz, plagioclase, biotite, hornblende, epidote, garnet, muscovite, apatite, opaque minerals, and zircon with secondary chlorite and sericite. Polygranular quartz aggregates are from 1-40 mm long and impart a prominent ribbony foliation to most outcrops. Locally the quartz aggregates and plagioclase crystals define relict porphyritic textures. The color index of these rocks is < 25%.

NOTE: Trondhjemitic and tonalitic gneiss in the Twilight Gneiss contain layers of fine- to coarse-grained, strongly foliated to massive, amphibolite that are from < 1-2 m in thickness. Individual layers are not shown on the map, but the trend of S_0 defined by alternating layers of amphibolite and intermediate gneisses in the Twilight Gneiss are indicated. These amphibolite layers are interpreted as swarms of gabbroic sills and dikes that intruded rocks in the Twilight Gneiss and Irving Formation prior to compressional deformation and amphibolite facies metamorphism. The amphibolite layers are composed largely of hornblende, plagioclase, quartz, epidote, and garnet. Minor constituents include sphene, apatite, opaque minerals, and secondary chlorite and sericite. In an aureole around the Electra Lake Gabbro these layers are cut by numerous tension fractures that are commonly filled with unfoliated quartzo-feldspathic stringers and veins that extend from strongly foliated and deformed trondhjemitic gneiss. Near the margins of the Electra Lake Gabbro there are zones of melt breccia in which randomly oriented angular to subangular blocks of amphibolite are set in a matrix of unfoliated granitoid that is similar in composition to the trondhjemitic gneisses. Tension fractures and melt breccia zones are also locally filled with fine-grained to pegmatitic granitoids that are related to the Eolus Granite. Brittle fractures in the amphibolites locally become mesoscopic ductile shear zones in adjacent layers of trondhjemitic and tonalitic gneiss. These shear zones deflect foliation in the gneisses, commonly form conjugate sets, and provided local pathways for partial melt injection. Shear fractures and shear zones are dominated by northeast and northwest trending arrays that typically record sinistral and dextral sense of movement, respectively. These features are interpreted as evidence for partial melting of trondhjemitic gneiss in the Twilight Gneiss during emplacement of the Electra Lake Gabbro and coeval Eolus Granite under regional or sub-regional ~N-S contraction and ~E-W extension . Synchronous E-W extension during shortening is reflected by E-W to NE-SW tectonic foliation within ~1435 Ma dikes and pluton margins of the Eolus Granite, dominant N-S trends of ~1435 Ma granitoid and gabbroic dikes, and possibly by E-W to NW-SE primary magmatic foliation in the Electra Lake Gabbro. Extension also caused boudinage that is defined by brittle and ductile detachment of melt-injected amphibolite layers in the Twilight Gneiss, necking that both deforms and is cut by partial melt injections, and attenuated E-W trending Eolus Granite dikes.

Irving Formation (Early Proterozoic Volcanogenic and Associated Intrusive Rocks)

m **Mafic Schist & Gneiss**--Fine- to coarse-grained, strongly foliated to massive amphibolite that is interpreted as metamorphosed basaltic volcanic rocks and associated gabbroic intrusive rocks. The amphibolite is composed chiefly of hornblende, plagioclase, epidote, quartz, and garnet. Primary features were not observed in this unit in the map area, however, similar lithologies in other exposures of the Irving Formation contain relict pillow structures, pillow breccias, porphyritic and amygdaloidal textures, subophitic to ophitic textures, and additional features that support a volcanic or intrusive origin.

fm **Felsic, Intermediate, and Mafic Schist & Gneiss**-Fine- to medium-grained felsic to intermediate schist and gneiss interlayered with fine- to coarse-grained amphibolite. Layers are meters to tens of meters thick. Felsic and intermediate lithologies are interpreted as metamorphosed rhyolitic to dacitic tuffs and reworked volcanic deposits. These rocks are locally cut by swarms of medium- to coarse-grained quartzo-feldspathic stringers and ribbons that are commonly <1-6 cm thick. The stringers trend subparallel to compositional layering and S_1 & S_2 tectonic foliation, and locally define tight and isoclinal F_2 folds. Transposition and detachment of these stringers has locally produced an augen structure in which quartzo-feldspathic "eyes" are set in a groundmass of finer-grained schist. Amphibolite layers in this unit are composed of hornblende, plagioclase, epidote, quartz, and garnet. Felsic to intermediate rocks in this unit are composed largely of quartz, feldspar, biotite, muscovite, and garnet with color indices ranging from 5-50%. Locally, these rocks show a pronounced layering which is interpreted as primary bedding and lamination. Preliminary U-Pb zircon data for a sample of fine-grained felsic schist at location G25 suggests an age between 1795 and 1805 Ma.

Contact--Dashed where approximately located; short dashed where inferred; dotted where concealed.

Fault--Dashed where approximately located; short dashed where inferred; dotted where concealed. Ball and Bar on the downthrown side. Arrows indicate relative lateral movement.

Strike and dip of bedding, layering, or igneous dikes and sills

10° Inclined

Vertical

Strike and dip of tectonic foliation

5° Inclined

Vertical

75° Strike and dip of foliation is parallel to compositional layering

Folded--Showing map view of fold(s)

Strike and dip of primary flow foliation in intrusive igneous rocks

50° Inclined

5° Bearing and plunge of mineral lineation--Tail of arrow at point of measurement; may be combined with foliation symbol

23° Bearing and plunge of boudinage

Locations of en-echelon to randomly oriented tension fractures--Arrows indicate the dominant sense of shear of en-echelon fractures as indicated by their orientation relative to compositional layering

Mesoscopic folds--General map view of fold(s) indicated by pattern

40° Strike and dip of axial surface

27° Bearing and plunge of axis; may be combined with strike and dip of axial surface

Location of sample used for U-Pb zircon dating

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.